Applying abundance/biomass comparison curves to small mammals: a weak tool for detect urbanization-related stress in the assemblages?

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Abstract
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Urbanization is a form of pervasive human-induced disturbance. We tested the effectiveness of Abundance/Biomass Comparisons (ABC) as an approach in detecting stress due to landscape urbanization in large small mammal assemblages obtained from pellets of Barn Owl (*Tyto alba*; Strigiformes). We compared three assemblages sampled in not urbanized contexts (agro-mosaic landscapes) with three assemblages preyed in highly urbanized contexts. In all assemblages, the role of strictly synanthropic species (in our case: rodents) emerged since almost all of total biomass was assigned to these species: indeed, everywhere (both in agro-mosaic and urbanized sites) species of low trophic level (i.e. omnivorous/herbivorous rodents) significantly prevail in biomass when compared to insectivorous species (i.e. shrews, Soricomorpha) linked to less anthropized habitats. This biomass dominance in rodent species is highlighted by the data on evenness, showing lower values in biomass when compared to abundance. This pattern did not match with the classic assumption expressed by the ABC model (i.e., species with higher biomass are typical of undisturbed assemblage) and could be wrongly interpreted. Our study evidenced as ABC approach is a not reliable tool to detect the effect of urbanization as landscape disturbance acting on small mammal assemblages. Therefore we suggest that the ABC assumptions are not universal but limited only to assemblages where high body mass species coincide to species of a higher trophic level.

Keywords
abundance, biomass, dominance, disturbance, evenness, Italy

Introduction

Urbanization is a form of worldwide human-induced disturbance which may disrupt dominance patterns in biological assemblages, favouring generalist and synanthropic species and impacting on more specialized taxa (McDonald et al., 2008). Therefore it could be possible to detect the effects of this disturbance analysing the patterns in relative dominance among species (Dornelas et al., 2011).

Species dominance can be represented using Abundance/Biomass Comparison curves (ABC), which

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provide indication of the disturbance-related stress acting on species assemblages (Lambshead et al., 1983; Warwick, 1986). ABC curves are built using two different measures of cumulative frequency for each species, one based on abundance and another based on biomass. This approach is based on the assumption that in disturbed habitats, small-sized species (i.e., generalist species with low body mass, generally of low trophic level) tend to increase in abundance; consequently, the abundance curves approach an asymptote before the biomass curves (Magurran and McGill, 2011). On the contrary, in undisturbed habitats the opposite pattern may be observed, with the biomass curves cumulating before the abundance curves (abundance curves will be lower when compared to biomass ones), an indication that a higher number of specialized large-sized species of high trophic level occur. Therefore, when comparing both abundance and biomass curves, we may obtain information on the level of disturbance affecting the assemblage (Craeymeersch, 1991; Yemane et al., 2005; Dornelas et al., 2011).

However, Warwick and Clarke (1994) highlighted as the assumption of ABC curves might be valid only for groups where species having larger biomass inhabit less disturbed habitats. For example, in small mammals, a group sensitive to urbanization (Battisti et al., 2017), synanthropic species of low trophic level (rodents as *Rattus* and *Mus*) show a larger body mass when compared to specialized species of high-trophic level as shrews (Soricomorpha), these last having a lower individual body mass (and consequently a low biomass at assemblage level). Therefore, for this group the ABC approach could be a weak tool to indicate the level of disturbance-induced stress on assemblages.

In this note we tested the prediction that ABCs could be a weak tool to detect disturbance-induced stress in small mammals. In this regard, we compared assemblages preyed in not urbanized contexts (agro-mosaic landscapes) with others preyed in highly urbanized contexts. To our knowledge this is the first study using ABC curves applied to urbanized environments, considering urbanization as a stress acting on small mammal assemblages.

Materials and methods

Indirect sinecological information on small mammal assemblages can be obtained analyzing preys (diagnostic skulls and bones) occurring in owl physiological pellets (Avenant, 2005). From the national data base (Ruffo and Stoch, 2006), we selected six sites where small mammal assemblages have been recorded from Barn Owl (*Tyto alba,* Strigiformes) pellets: three sites located in less disturbed landscapes (agro-mosaics, mainly characterized by oak wood fragments embedded in cropland matrices) and three sites located in highly disturbed (urbanized) landscapes (see caption Table 1), all belonging to the same bioclimatic (Mediterranean) region (see references for further details).

The analysis of land use was based on the photointerpretation of satellite images deriving to Corine Land Cover (http://groupware.sinanet.isprambiente.it/) updated 2018. For each site, it has been drawn a buffer of 1.5 km radius defining the per-cent cover for forests, croplands and urbanized area.

For each preyed species, we obtained the relative frequency both for abundance (Fr_N) and biomass (Fr_B). From each site, we obtained number of species (S) and normalized species richness (Margalef index: Dm = S – 1/ logN). Since in urbanized habitats, abundance frequencies could be more evenly distributed when compared to biomass frequencies (i.e., evenness is higher in biomass frequencies), we calculated the evenness index both on Fr_N and Fr_B values (respectively E_N and E_B), as E = H'/ ln(S), where H' is the Shannon-Wiener diversity index as

Table 1. Structural metrics of small mammal assemblages preyed by *Tyto alba*. S, number of species; Dm, normalized species richness (Margalef index); Hi_N, Shannon-Wiener diversity index (on abundance data); Hi_B, Shannon-Wiener diversity index (on biomass data); e_N, evenness index (on abundance data); e_B, evenness index (on biomass data). F and p-values for ANCOVA analysis were reported. Not urbanized sites: 1. Mole del Mignone (Viterbo; 42°10'N; 11°49'E): 96.87% croplands; 3.13% forests; 2: Mallo (Pescara; 42°27'N; 13°53'E): 80.21% croplands; 18.56% forests; 3: Marana di Montereale (L'Aquila; 42°29'N; 13°13'E): 78.04% forests; 18.24% croplands. Urbanized sites: 4: Due Ponti (Rome; 41°57'N; 12°28'E), 67.09% urbanized; 32.84% croplands; 5: Valle della Caffarella (Rome; 41°51'N; 12°30'E), 60.77% urbanized; 29.23% croplands; 6: Villa Pamphili (Rome; 41°53'N; 12°26'E), 85.7% urbanized; 14.3% croplands

	Not urbanized (agro-mosaic) sites			Urbanized sites		
	1	2	3	4	5	6
S	7	10	9	10	7	7
Dm	1.68	1.62	1.47	1.34	1.58	1.76
H'_N	1.36	1.74	1.65	1.39	1.27	1.43
H'_B	1.23	1.39	1.45	1.21	0.66	1.22
e_N	0.70	0.76	0.75	0.60	0.65	0.73
e_B	0.63	0.61	0.66	0.52	0.34	0.63
ANCOVA	$F_{2,11}$ = 0.001 p= 0.978	$F_{2,17}$ = 0.000, p = 1	$F_{2,15}$ = 0.000, p = 1	$F_{2,17}$ = 0.000, p = 1	$F_{2,11}$ = 0.000, p = 1	$F_{2,11}$ = 0.000, p = 1

H' = – Σ Fr ln Fr, and S is the number of species (for diversity metrics: Magurran and McGill, 2011). Finally, we ranked the species along a log-transformed x-axis in order to obtain two better-fit curves (with equations and coefficient of determination, R^2), both for abundance and biomass (ABC curves; Warwick, 1986).

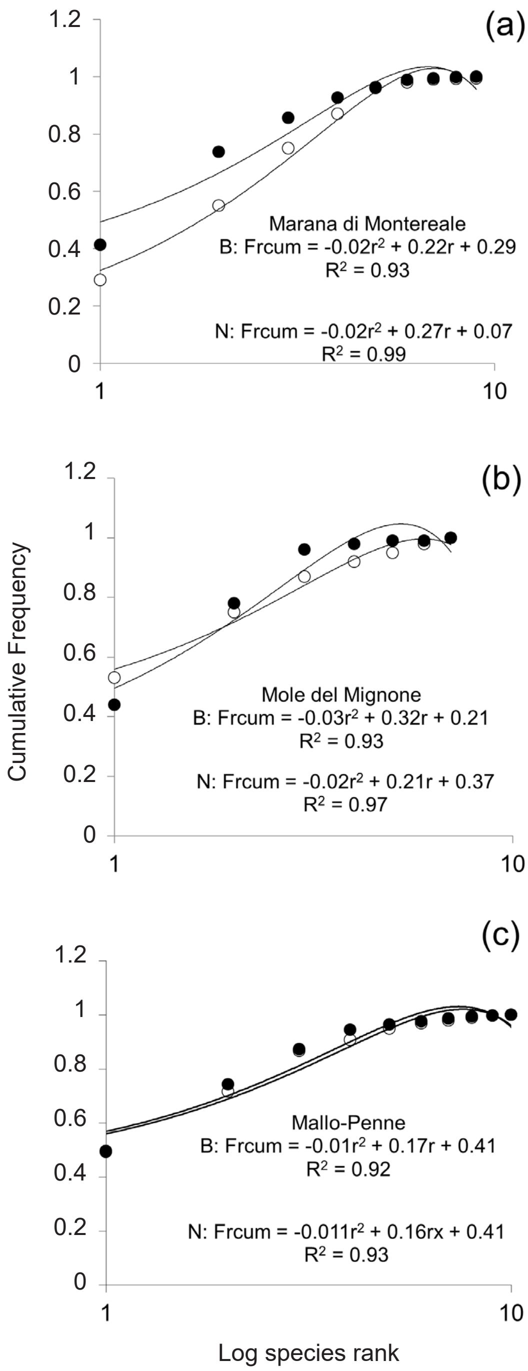

Fig. 1. ABC plots for not urbanized sites: Marana di Montereale (a), Mole del Mignone (b), Mallo-Penne (c). Biomass (B) frequencies: black points; abundance (N) frequencies: white points. Better fit (polynomial line) equation line and coefficient of determination (R^2) are reported.

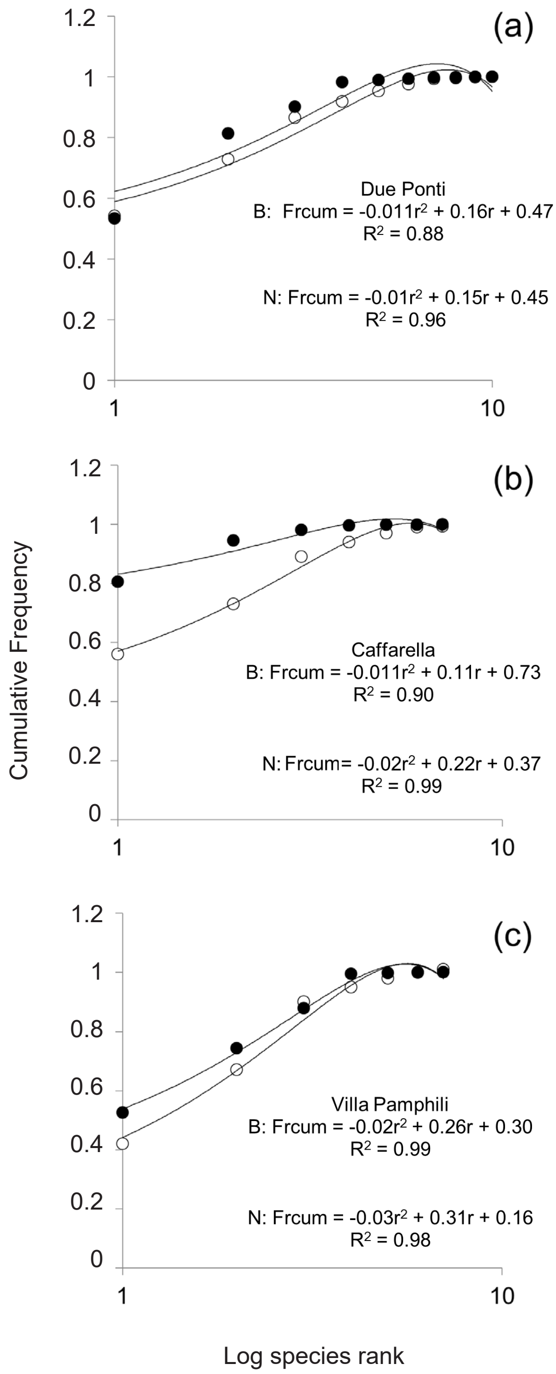

Fig. 2. ABC plots for urbanized sites: Due Ponti (a), Caffarella (b) and Villa Pamphili (c). Biomass (B) frequencies: black points; abundance (N) frequencies: white points. Better fit (polynomial line) equation line and coefficient of determination (R^2) are reported.

To test for differences between the better-fit regression lines in ABC approach we performed an Analysis of Covariance (ANCOVA), using abundance or biomass as the grouping variables and cumulative guild rank as a covariate (SPSS 13.0 software). For systematic nomenclature we followed Amori et al. (2008).

Results

ABC curves show as in all sites (both agro-mosaics and urbanized), biomass curves intersect or are located above the abundance curve (better-fit curves; everywhere $R^2 \geq 0.85$; Fig. 1, Fig. 2; data set in Appendix 1), due to the generally highest values in Fr_B when compared to Fr_N. There are not significant difference between curves ($p > 0.01$; ANCOVA test; Table 1). Evenness and Shannon-Wiener diversity indices are ever lower when applied to Fr_B when compared to Fr_N (Table 1).

When analyzing biomass, the role of strictly synanthropic species (rodents as *Rattus* and *Mus*) was further emphasized since almost all of total biomass was assigned to these species. Everywhere (both in agro-mosaic and urbanized sites) species of low trophic level significantly prevail in biomass when compared to insectivorous species of higher trophic level (i.e. shrews, Soricomorpha) linked to less urbanized habitats. This concentration of biomass in these species is highlighted by evenness, this parameter showing lower values in biomass when compared to abundance (Table 1).

Discussion

Abundance/Biomass Comparisons assume that disturbed assemblages will be characterized by dominant species with a lower biomass when compared to undisturbed assemblage (Warwick, 1986), a pattern largely observed (e.g. Meire and Dereu, 1990; Campos-Vàsquez et al., 1999). Consequently, in urbanized habitats the largest species are unlikely to be dominant and the distribution of biomass among species will be less even when compared to the distribution of abundance: i.e. in an ABC diagram the biomass curve will lie below the abundance curve; Magurran and McGill, 2011). However, our data suggest that when the ABC model is applied to assemblages where the species with highest biomass inhabit disturbed habitats (as in small mammals) a cautionary interpretation is needed. Indeed, we obtained a pattern where (i) biomass line intersects or is above the abundance curve, independently from the level of disturbance (agro-mosaic vs. urbanized), and (ii) curves are not significantly different. Following the ABC assumptions, this pattern should indicate a moderate level of disturbance without distinguish between disturbed and undisturbed assemblages (Magurran and McGill, 2011). Instead, in our case, this pattern is due only to the ubiquitous presence of large synanthropic species of low trophic level (rodents, mainly *Rattus* sp.), largely represented in urbanized habitats.

ABC patterns in small mammals are very different when compared to assemblages where this model was originally applied (i.e., where large body mass species are of higher trophic level and inhabiting poor disturbed habitats). Yet Prete et al. (2012) reported that in small mammal assemblages living in anthropized habitats, (i) synanthropic omnivorous species of low trophic level and high biomass (*Rattus* spp.) dominated in stressed contexts and (ii) small carnivorous (as shrews, Soricomorpha) of higher trophic level but very low body mass, associated to undisturbed habitats, are scanty. In these disturbed assemblages, the increase in abundance of large species with high body mass may correspond to early cumulating biomass curves that may be wrongly interpreted as typical of low disturbed assemblages.

Data on evenness support our considerations: contrary to expected, we observed a lower value of biomass evenness when compared to abundance evenness. This pattern is typically obtained in undisturbed assemblages but, in our case, it can be observed everywhere (in not urbanized and urbanized contexts), due to the dominance of the ubiquitous synanthropic species.

This study corroborates the cautionary interpretation of ABC curves yet highlighted for other biological groups (Warwick and Clarke, 1994; Smith and Rissler, 2010; Solyanko et al., 2011). Recently, Battisti (2018) observed that the comparison of biomass vs. abundance curves could be a weak approach to detect human-induced stress in insular birds. In this regard, the assumptions linked to the ABC curves (i.e., in disturbed assemblage species with higher biomass are less represented and biomass curve underlie the abundance curve) is probably not universal but limited only to assemblages where species with higher body mass have higher trophic level.

However, we analyzed preyed assemblages indirectly obtained from *Tyto alba* pellets. Although this technique is widely used worldwide to characterize the small mammal communities, in this type of sampling there is the assumption that the relative frequencies in abundance (and biomass) are proportional to the true abundance into the wild, an assumption difficult to test (Luiselli and Capizzi, 1996). Moreover, in *Tyto alba* pellets several species of small mammals are not preyed and were therefore excluded from the analysis (e.g. squirrel, hedgehog, dormices species as *Glis*). This fact could affect our data (e.g. truncating the biomass frequency curve at high values). Therefore our considerations should be limited only to preyed communities occurring in this specific '*Tyto alba*-small mammal' trophic system.

According to Smith and Rissler (2010), the ABC applications need to take into account both the specific ecological characteristics of studied taxa and the natural history of study sites to avoid incorrect interpretations of disturbance responses. We think that also the type of disturbance analyzed and the method used for data sampling could affect the ABC patterns and its reliability in detecting disturbance-induced stresses for specific groups.

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Appendix 1.

Species assemblages preyed by *Tyto alba* in not urbanized (agro-mosaic) and urbanized sites. Number of individuals (N), biomass (B) and its frequencies (respectively Fr_N and Fr_B) have been reported.

Species	Not urbanized (agro-mosaic)											
	Mole del Mignone				Mallo-Penne				Montereale			
	N	FrN	B	FrB	N	FrN	B	FrB	N	FrN	B	FrB
Sorex minutus									48	0.09	336	0.04
Sorex sp.					44	0.15	75	0.01	107	0.20	1070	0.12
Neomys sp.					3	0.01	440	0.07	2	0.004	50	0.01
Suncus etruscus	28	0.12	56	0.01	6	0.02	12	0.002				
Crocidura leucodon	5	0.02	50	0.01	12	0.04	120	0.02	64	0.12	640	0.07
Crocidura suaveolens	12	0.05	48	0.01	12	0.04	48	0.01	5	0.01	20	0.002
Muscardinus avellanarius									1	0.002	30	0.003
Microtus savii	8	0.03	168	0.02	145	0.49	3045	0.49	140	0.26	2940	0.32
Myodes glareolus					3	0.01	63	0.01	11	0.02	231	0.03
Apodemus sp.	53	0.22	1272	0.18	64	0.22	1536	0.25	156	0.29	3744	0.41
Mus musculus	128	0.53	2432	0.34	1	0.003	19	0.003				
Rattus sp.	8	0.03	3200	0.44	2	0.01	800	0.13				
Total	242		7226		292		6158		534		9061	

Species	Urbanized											
	Due Ponti				Caffarella				Villa Pamphili			
	N	FrN	B	FrB	N	FrN	B	FrB	N	FrN	B	FrB
Sorex minutus	3	0.001	237	0.01	1	0.003	79	0.003				
Sorex sp.	2	0.001	20									
Neomys sp.												
Suncus etruscus	22	0.02	44		10	0.03	20	0.001	5	0.03	10	0.001
Crocidura leucodon	16	0.02	160						1	0.01	10	0.001
Crocidura suaveolens	32	0.03	128		7	0.02	28	0.001	4	0.02	16	0.002
Muscardinus avellanarius	2	0.001	60									
Microtus savii	512	0.54	10752	0.28	188	0.56	3948	0.14	79	0.42	1659	0.22
Myodes glareolus												
Apodemus sp.	130	0.14	3120	0.08	17	0.05	408	0.01	43	0.23	1032	0.14
Mus musculus	177	0.19	3363	0.09	54	0.16	1026	0.04	47	0.25	893	0.12
Rattus sp.	51	0.05	20400	0.53	57	0.17	22800	0.81	10	0.05	4000	0.53
Total	947		38284		334		28309		189		7620	